ARM/GCSS/SPARC TWP-ICE NWP Intercomparison Study

Yanluan Lin, email: yanluan.lin@noaa.gov
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1 Introduction

Clouds have been shown to introduce the largest uncertainty in the GCM projection for the future climate. Convection and stratiform cloud are generally parameterized in GCMs using convective parameterizations and large-scale cloud schemes separately. Corresponding to this separation, clouds have sources from convective parameterization (both deep and shallow convection) and stratiform cloud (large-scale) parameterization in GCMs. In addition, cloud microphysical processes, which occur over a wide range from microns to meters, need to be parameterized. Cloud and convection parameterizations in atmospheric numerical models are diverse and might include large unconstrained uncertainties.

Evaluation of GCM clouds directly using field experiment observations is difficult since climate simulations represent statistics of the atmospheric states. A better approach, Climate Change Prediction Program (CCPP-ARM Parameterization Testbed, CAPT), which initializes climate models with analysis data from data assimilation system for short-range weather forecasts and then evaluate the forecast using field measurements, has been a valuable tool for model evaluation and improvement (Phillips et al. 2004).

Tropical Warm Pool-International Cloud Experiment (TWP-ICE) has collected comprehensive cloud measurements during the period from 20 Jan to 13 Feb 2006 near Darwin, Northern Australia (May et al. 2008). Using CAPT approach, this GCM numerical weather prediction (NWP) intercomparison study will not only compare and investigate performance of various parameterization schemes, but also will provide a comparison with other model intercomparison studies, which include Cloud Resolving Models (CRMs), Limited Area Models (LAMs), and Single Column Models (SCMs).

2 Objectives and intercomparison focus

Cirrus has a large radiation impact on the climate system and its representation in GCMs is critical for the radiation balance. Cirrus is formed by convection detrainment and large scale forcing among others. Its sources could be from both convective parameterization and stratiform cloud scheme in GCMs. Microphysical and radiative characteristics of cirrus need to be represented realistically in GCMs. This study focuses on the evaluation of model simulated deep convection and cirrus in terms of its source, sink and evolution in various GCMs.

Two types of cirrus are measured during TWP-ICE, one is related with the " Landphoon " without local convection sources, another is locally produced during the active monsoon period. These two contrasting cirrus generation mechanisms provide a good test of GCM cirrus simulations. Some motivations for the study are:

- How do GCMs perform given realistic large scale initialization?
- What are the systematic bias in GCM simulations of tropical deep convection and ice clouds using CAPT approach?
- How does model performance vary under different dynamic regimes (active and suppressed monsoon period)?
- How does model simulation compare with SCM results, which does not have the feedback to large-scale forcing?
- How does cloud and precipitation systematic bias related with deep convection parameterization and large-scale cloud scheme used?

3 Case description

3.1 Simulation time period

Four distinct periods have been identified during the TWP-ICE (May et al. 2008).

a. 19-25 Jan. Active period with a MCS passed on 24th Jan and moved to south and developed into a low pressure system

b. 26th Jan - 2nd Feb. Suppressed period with long lasting Anvils.

c. 3-5 Feb. Clear period with no surface precipitation near the Darwin site.

d. 6-13 Feb. Break period with more localized convection.

To get a continous picture of the tropical system movement and evolution, model simulations will cover the whole period of TWP-ICE (0000 UTC,18 Jan to 0000 UTC 14 Feb 2006). Detailed analysis and investigation will focus on some sub-periods of interest, such as period a and b. This period is consistent with the CRM simulaitons and thus extra diagnostics from CRMs could be used for the model evaluation. Analysis will include the general model performance with emphasis on convection and cirrus clouds. Microphysics of cirrus will be emphasized.

3.2 Potential observational data for comparison

Comprehensive measurements have been collected during TWP-ICE. Table 1 describes a subset of observational data available for model comparison and evaluation.

3.3 Simulation approach

Different from other intercomparison projects, a global simulation requires some specific configuration and setup at each modeling center. The following provides some guidelines for the basic requirements of the model simulations.

a: Resolution

Considering the fact that high-resolution global forecast model has evolved quickly, we plan to have a resolution component in this study. The idea is to run the model at climate resolution (around 2 degrees, standard run) plus one or two high-resolution runs (one or half degree, high-resolution runs). Regarding the model physics to be used, if the model is typically run at different resolutions then the appropriate physics settings for that resolution should be used. Otherwise, physics should be kept constant for different resolution simulations.

Table 1: TWP-ICE available observations

Name	including variables	Description
large-scale forcing	$Q1, Q2, SH, LH$, SFC and TOA radiative fluxes, PR, LWP, q_v	Xie/Zhang variational analysis
TCPRHP ground retrieval	IWC, LWC, LWP, IWP, SFC and TOA radiative fluxes, radiative heating profile,	McFarlane et al.
C-Pol radar retrieval	PR, latent heating profile	Schumacher
Surface OBS	SH, LH, radiative fluxes, Surface PR, U, V, T	various surface measurements
microphysical data	IWC, ice particle size, particle projected area, size distribution,optical thickness	in situ aircraft measurements
satellite retrieval	IWC,IWP,LWP,cloud cover,height	VISST,TRMM,MODIS

b: Simulation time frame

The forecast will be initialized at 00Z each day and run out to 5 days. Daily f24-f48 forecast chunks will be combined to generate a continous forecast from 00Z 18 Jan to 00Z 14 Feb.

c: Initialization

The ECMWF analysis at 6h interval will be used for the model initialization of wind, temperature, moisture, and surface pressure . Some centers have their own data assimilation component and they can submit the runs using their own assimilation initialization.

For the lower boundary conditions, such as land, SST, and sea ice, modeling centers are free to choose their own initialization methods. It is encouraged to spin up the model land to the start time of simulations. Aerosol and ozone could be specified using climatological datasets.

Nudging is not encouraged, but use and how to use nudging is up to participants. However, only the free forecast period will be compared. (e.g. if you run the nudging for the first day, your real forecast is counted from the second day).

Please sumbit a text file briefly describing the model configuration and setup with major references of the model.

4 Time plan and data submission

4.1 Deadline

Submit the model outputs by Oct 1st, 2009. Earlier results and provisional results are also accepted.

4.2 Data submission

Model results are requested for 18-45 Julian days (18 Jan to 14 Feb 2006). To save the disk space, only data in the region (-25 to 0 degree south, and 121.25 to 141.25 degree east) at every hour interval are required in netcdf format. Required variables are detailed in Table 2 and 3. The table does not mean to be exhaustive and you can have more variables (e.g. some convective parameterization generates its own cloud ice, liquid, and cloud fraction). Also, if you have other microphysical variables, such as snow, rain, graupel, cloud droplet number concentration, or ice number concentration, please also sumbit them. You can have all these variables in one netcdf file.

If you have access to an ISCCP simulator and can produce ISCCP diagnostics, then these diagnostics can be provided in a separate netcdf file.

Also, please save those detailed diagnostics from deep convection and large-scale parameterizations in case we need further analyses.

4.3 Publications

One paper will be possible from this intercomparison project depending on the final results we receive and the focus of the study. Submitted results will be included in these papers and participants are included as co-authors.

References

May, P. T., J. H. Mather, G. Vaughan, C. Jakob, G. M. McFarquhar, K. N. Bower, and G. G. Mace (2008), The Tropical Warm Pool International Cloud Experiment, Bull. Am. Meteorol. Soc., 89, 629-645, doi:10.1175/BAMS-89-5-629.

Phillips T. J., Coauthors, 2004: Evaluating parameterizations in general circulation models: Climate simulation meets weather prediction. Bull. Amer. Meteor. Soc., 85, 1903-1915.

Table 2: Model outputs and naming conventions

Name	*Units*	*Description*
3-D variables		
T	K	temperature
θ	K	potential temperature
qv	kg/kg	water vapor
RH	$unitless$	relative humidity
qi	kg/kg	cloud ice
qw	kg/kg	cloud water
qa	$unitless$	cloud fraction
u	m/s	eastward wind
v	m/s	northward wind
w	m/s	vertical wind
rho	kg/m^3	air density
Q_1	K/day	apparent heat source
Q_2	$g/kg/day$	apparent moisture sink
P	Pa	pressure (if 3-D)
M_{cu}	$kg/m^2/s$	convective updraft mass flux
M_{cd}	$kg/m^2/s$	convective downdraft mass flux
TQ_{sw}	K/day	total sky SW heating rate
TQ_{lw}	K/day	total sky LW heating rate
CSQ_{sw}	K/day	clear sky SW heating rate
CSQ_{lw}	K/day	clear sky LW heating rate
$d\theta^{LS}$	K/day	$d\theta$ due to large scale
dq^{LS}	$g/kg/day$	dqv due to large scale
$d\theta^{CONV}$	K/day	$d\theta$ due to convection
dq^{CONV}	$g/kg/day$	dqv due to convection
$d\theta^{BL}$	K/day	$d\theta$ due to BL nad vertical mixing
dq^{BL}	$g/kg/day$	dqv due to BL and vertical mixing
$d\theta^{CLD}$	K/day	$d\theta$ due to LS clouds and prep
dq^{CLD}	$g/kg/day$	dqv due to LS clouds and prep

Table 3: model output continued

2-D variables		
U_{10}	m/s	10 m U wind
V_{10}	m/s	10 m V wind
T_2	K	2 m temperature
T_g	K	ground temperature
RH_2	$unitless$	2 m relative humidity
$SWDN_{SFC}$	W/m^2	short wave down at surface
$SWUP_{SFC}$	W/m^2	short wave up at surface
$LWDN_{SFC}$	W/m^2	long wave down at surface
$LWUP_{SFC}$	W/m^2	long wave up at surface
$SWDN_{TOA}$	W/m^2	short wave down at TOA
$SWUP_{TOA}$	W/m^2	short wave up at TOA
$LWUP_{TOA}$	W/m^2	long wave up at TOA
LWP	kg/m^2	liquid water path
PWV	kg/m^2	precipitable water
IWP	kg/m^2	ice water path
SH_{SFC}	W/m^2	sfc sensible heat flux
LH_{SFC}	W/m^2	sfc latent heat flux
PR	mm/h	sfc precipitation rate
PR_{CONV}	mm/h	sfc convective precipitation rate
PR_{LS}	mm/h	sfc LS precipitation rate
other variables		
$time$	$hour$	time
$pres$	Pa	pressure
$hght$	m	height
ter	m	terrain height
lat	$degree$	latitude
lon	$degree$	longitude